JC18 Rec'd PCT/PTO 01 AUG 2001

FORM PTO-1390 (Modified) (REV 5-93) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371		ATTORNEY'S DOCKET NUMBER 085874-0353
		U.S. APPLICATION NO. (If known, see 37 C.F.R. 1.5) Unassigned 09/890466
INTERNATIONAL APPLICATION NO. PCT/DE00/00252	INTERNATIONAL FILING DATE January 28, 2000	PRIORITY DATE CLAIMED February 2, 1999

TITLE OF INVENTION
SOUND GENERATOR WITH A PUMP ACTUATOR

APPLICANT(S) FOR DO/EO/US
Oskar BSCHORR, Hans-Jochen RAIDA

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a FIRST submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a SECOND or SUBSEQUENT submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   - ☒ is transmitted herewith (required only if not transmitted by the International Bureau).
   - ☐ has been transmitted by the International Bureau.
   - ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   - ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   - ☐ have been transmitted by the International Bureau.
   - ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   - ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).
11. ☐ Applicant claims small entity status under 37 CFR 1.27 .

Items 12. to 17. below concern other document(s) or information included:

12. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
13. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
14. ☒ A FIRST preliminary amendment.
    ☐ A SECOND or SUBSEQUENT preliminary amendment.
15. ☐ A substitute specification.
16. ☐ A change of power of attorney and/or address letter.
17. ☐ Other items or information:

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U.S. APPLICATION NO. (If known, see 37 C.F.R. 1.50)	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
Unassigned 09/890466	PCT/DE00/00252	085874-0353

18. ☒ The following fees are submitted:

	CALCULATIONS	PTO USE ONLY
Basic National Fee (37 CFR 1.492(a)(1)-(5): Search Report has been prepared by the EPO or JPO $860.00		
International preliminary examination fee paid to USPTO (37 CFR 1.482) $690.00		
No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2) $710.00		
Neither international preliminary examination fee (37 CFR 1.482) nor International search fee (37 CFR 1.445(a)(2)) paid to USPTO $1,000.00		
International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) $100.00		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$1,000.00	
Surcharge of $130.00 for furnishing the oath or declaration later than 20 Months from the earliest claimed priority date (37 CFR 1.492(e))		

Claims	Number Filed		Included in Basic Fee		Extra Claims		Rate		
Total Claims	58	-	20	=	38	×	$18.00	$684.00	
Independent Claims	4	-	3	=	1	×	$80.00	$80.00	
Multiple dependent claim(s) (if applicable)							$270.00		

TOTAL OF ABOVE CALCULATIONS =	$1,764.00	
Reduction by ½ for filing by small entity, if applicable.	$0.00	
SUBTOTAL =	$1,764.00	
Processing fee of $130.00 for furnishing English translation later the 20 months from the earliest claimed priority date (37 CFR 1.492(f). +		
TOTAL NATIONAL FEE =	$1,764.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +		
TOTAL FEES ENCLOSED =	$1,764.00	

Amount to be: refunded	$
charged	$

a. ☒ A check in the amount of $1,764.00 to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. 19-0741 in the amount of $1,764.00 to the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 19-0741. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

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REGISTRATION NUMBER 28,163

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Attorney Docket No. 085874/0353

In re Patent Application of

Oskar B. SCHORR et al.

Serial No. Unassigned

Group Art Unit: Unassigned

Filed: Herewith

Examiner: Unassigned

For: SOUND GENERATOR WITH A PUMP ACTUATOR

PRELIMINARY AMENDMENT

Commissioner for Patents
Washington, D.C. 20231

Sir:

Prior to examination on the merits, please amend this application as follows.

IN THE SPECIFICATION

In accordance with 37 C.F.R. §1.121(b)(1), please amend the specification by inserting new paragraphs (section headings) as follows:

Page 2, line 6: Insert the following heading:

BACKGROUND ART

Page 2, line 25: Insert the following heading:

SUMMARY OF THE INVENTION

Page 5, at the top of the page, before the first line: Insert the following heading:

BRIEF DESCRIPTION OF THE DRAWINGS

Page 5, line 15: Insert the following heading:

DETAILED DESCRIPTION

IN THE CLAIMS

Please Cancel claims 1-9 without prejudice or disclaimer, and substitute therefor new claims 10-67, as follows:

10. Sound generator for anti-sound, signal, speech and music reproduction from the infrasound to the ultrasound range and in response to a required sound signal, the sound generator comprising:

two acoustically-separated volumes;

a sound outlet operatively coupled to at least one of said acoustically-separated volumes;

a pump system, including at least one pump, adapted to convey a fluid volume flow between said acoustically-separated volumes and through said sound outlet, the direct flow component of the fluid volume flow being zero; and

means for modulating said fluid volume flow in response to said required sound signal.

11. Sound generator according to claim 10, wherein at least one of said acoustically-separated volumes is a buffer volume.

12. Sound generator according to claim 10, wherein the pump has a pumping frequency that is greater than or equal to the frequency of the required sound.

13. Sound generator according to claim 12, wherein said pumping frequency is large relative to the frequency of the required sound.

14. Sound generator according to claim 10, wherein the wavelength of the required sound is large relative to the diameter of the sound outlet, thereby to effect unipolar acoustic sound radiation.

15. Sound generator according to claim 10, comprising multiple pumps.

16. Sound generator according to claim 15, wherein the multiple pumps are phase-shifted relative to one another.

17. Sound generator according to claim 15, wherein said pumps are of differing sizes.

18. Sound generator according to claim 10, wherein the means for modulating comprises at least one valve.

19. Sound generator according to claim 10, wherein the pump is the means for modulating.

20. Sound generator according to claim 10, comprising a sensor adapted to record with high time resolution physical data of the pump system, the fluid within the buffer volume, the fluid volume flow or the emitted sound pressure.

21. Sound generator according to claim 20, wherein the sound generator further comprises a control unit for open or closed loop control of the pump system in dependence on the sensed data.

22. Sound generator according to claim 11, wherein said pump system comprises a flexible, actively displaceable wall in the buffer volume.

23. Sound generator according to claim 10, wherein said pump system produces volume displacement and/or pressure variation through a mechanism selected from the group consisting of turning parts, oscillating parts, rotating parts, mechanical waveguides, and by means of standing waves.

24. Sound generator according to claim 10, wherein said pump system has a fixed supply direction.

25. Sound generator according to claim 10, wherein said pump can be reversed and has suck and blow operation.

26. Sound generator according to claim 10, wherein said pump system supplies an analogue volume flow.

27. Sound generator according to claim 10, wherein said pump system supplies a digital volume flow.

28. Sound generator according to claim 10, wherein said pump system or its drive is cooled by the fluid itself.

29. Sound generator according to claim 10, wherein said pump system or its drive is cooled by thermal radiation.

30. Sound generator according to claim 11, wherein said buffer volume comprises a structure selected from the group consisting of a channel, a ring channel, a spiral, a disc, a box, a spherically shaped cavity, and an already existing cavity.

31. Sound generator according to claim 11, wherein a plurality of buffer volumes are operatively coupled to the pump system via movable separating walls or vibrating components.

32. Sound generator according to claim 11, further comprising means for damping standing waves in the buffer volume selected from the group consisting of passive absorbers, active sound damping means, and combinations thereof.

33. Sound generator according to claim 10, wherein said sound outlet is connected to two acoustically-separated volumes.

34. Sound generator according to claim 11, wherein in the buffer volume, as well as through the pressure of the fluid, energy is temporarily stored through a fluid flow or through reactive deflection of components.

35. Sound generator according to claim 10, comprising a plurality of sound outlets.

36. Sound generator according to claim 10, wherein said sound outlet is sealed with a membrane.

37. Sound generator according to claim 10, further comprising an aerodynamic diffuser mounted at the sound outlet.

38. Sound generator according to claim 10, further comprising an acoustical horn mounted at the sound outlet.

39. Sound generator according to claim 10, wherein said sound outlet is a channel.

40. Sound generator according to claim 10, further comprising active or passive acoustic dampers or resonators to damp or cancel the cyclic or other intrinsic sounds of the pump system.

41. Sound generator according to claim 10, wherein in front of and behind the sound outlet are situated reactive elements for sound amplification or filtering selected from the group consisting of Helmholtz resonators, $\lambda/4$ resonators, and an acoustic network.

42. Sound generator according to claim 10, wherein the sound outlet has a grid or fabric as dust and contact protection.

43. Sound generator according to claim 10, wherein said means for modulating comprises at least one valve.

44. Sound generator according to claim 10, wherein said means for modulating modulates the fluid volume flow through a mechanism selected from the group consisting of variation of the pump frequency, a variable pump stroke, switching on and off of individual pumps or fluid channels, the cyclic, amplitude or phase relationship between the modulation means and the pump system, via standing waves in the buffer volume, via a siren mechanism, and combinations thereof.

45. Sound generator according to claim 18, wherein said at least one valve modulates the fluid volume flow through amplitude, frequency or phase control.

46. Sound generator according to claim 18, wherein a plurality of valves modulate the fluid volume flow through the closing and opening of individual valves.

47. Sound generator according to claim 10, wherein, in a pump with one supply direction, the fluid volume flow is guided by two valves in front of and behind the pump according to the fluid volume flow modulation to be achieved.

48. Sound generator according to claim 10, wherein, in a pump with one supply direction, the fluid volume flow is guided by two valves in front of and behind the pump through flow deflection outwards or into the buffer volume respectively.

49. Sound generator according to claim 11, wherein the entire pump system or parts thereof, or the fluid in the buffer volume or in the sound outlet, undergo natural oscillation, thereby achieving passive modulation.

50. Sound generator according to claim 21, wherein said control unit compensates for the frequency-dependent functioning of the pump system and/or losses or non-linearities in the compression by the pump system.

51. Sound generator according to claim 10, comprising two pumps operating at high frequency with almost the same frequency, thereby to generate low-frequency useful sound radiation according to the Tartini effect.

52. Sound generator according to claim 10, comprising two or more pump systems or parts thereof having the same or opposing output directions, the pump systems or parts being linked electrically or mechanically, the linkage being controllable so as to achieve a modulation.

53. Sound generator according to claim 20, wherein said sensor records the pressure and/or temperature and/or fluid volume flow and/or the speed of the fluid volume flow and/or the sound pressure outside the pump or another variable characterising the fluid volume flow or movements of the pump system.

54. Sound generator according to claim 21, wherein said control unit compensates for the predetermined behaviour of said pump system, thereby rendering a sensor unnecessary.

55. Sound generator according to claim 10, comprising a plurality of sound outlets which form one-, two-, three-dimensional acoustic arrays or an end-fired line or a two-pole arrangement, whereby through amplitude, frequency and/or phase adjustment, any desired directional characteristic can be realised.

56. Sound generator according to claim 15, wherein said pumps are connected in series.

57. Sound generator according to claim 15, wherein said pumps are connected in parallel.

58. Sound generator according to claim 10, comprising a pipe, the sound outlet being located on the pipe.

59. Sound generator according to claim 11, wherein the buffer volume has an additional opening.

60. Sound generator according to claim 59, wherein the additional opening has a large flow resistance.

61. Watch, mobile telephone, remote control unit, pen, spectacles, jewellery, bank card, keyboard, screen, key ring, toy, household item, hearing aid or other component incorporating a sound generator according to claim 11, and whereby non-utilised or specially designed dead volumes are used as buffer volumes.

62. A loudspeaker system incorporating a sound generator according to claim 10.

63. A mobile or rotating component incorporating a sound generator according to claim 10.

64. A method of active noise control comprising the step of destructive interference using a sound generator according to claim 10.

65. Sound generator for anti-sound, signal, speech and music reproduction from the infrasound to the ultrasound range and in response to a required sound signal, the sound generator comprising:

first, second and third acoustically-separated volumes;

at least one sound outlet between said first and third and/or said second and third acoustically-separated volumes, respectively;

a pump system adapted to convey a fluid volume flow between said first and second volumes; and

means for modulating a fluid volume flow through said at least one sound outlet.

66. Fluid pumping device comprising an inlet, an outlet, a waveguide located therebetween and a vibrational exciter adapted to excite mechanical transverse waves in said waveguide, thereby to generate fluid flow from said inlet to said outlet.

67. Method of generating sound in response to a required sound signal, in particular reproducing anti-sound, signal, speech and music in the infrasound to the ultrasound range, the method comprising the steps of:

pumping a fluid volume flow between two acoustically-separated volumes and through a sound outlet such that the direct flow component of the fluid volume flow is zero; and modulating said volume fluid flow in response to said required sound signal.

REMARKS

Missing section headings have been added to the specification as suggested by 37 C.F.R. §1.77(c).

The new claims round out the scope of protection sought, and place the application in better form for examination by eliminating recitations that were not appropriate for U.S. practice.

Respectfully submitted,

8/1/2001
Date

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SHOULD ADDITIONAL FEES BE NECESSARY IN CONNECTION WITH THE FILING OF THIS PAPER, OR IF A PETITION FOR EXTENSION OF TIME IS REQUIRED FOR TIMELY ACCEPTANCE OF SAME, THE COMMISSIONER IS HEREBY AUTHORIZED TO CHARGE DEPOSIT ACCOUNT NO. 19-0741 FOR ANY SUCH FEES; AND APPLICANT(S) HEREBY PETITION FOR ANY NEEDED EXTENSION OF TIME.

Sound Generator with a Pump Actuator

The subject of the invention is a sound generator for eliminating interference by means of sound absorption, for speech and music reproduction and for acoustic warning and information signals.

The classic solution for said field of use is the electrodynamic loudspeaker with its numerous specialised versions. A problem with this technology, especially in the lower frequency range, is the large structural volume necessary, resulting from the elastic stiffness of the atmospheric air. With bass reflex speakers, resonant resilience reduction is achieved, and with it a reduction in enclosure volume, though at the cost of a worsened frequency response and phase response. Particularly disadvantageous with mobile deployment of electrodynamic loudspeakers is their poorer efficiency with the associated short loading cycles. Another solution technology uses pneumatic energy as the actuator. Ships' sirens, for instance, with rotating interrupter disks are ideally suited to the reproduction of loud and far-reaching sound mixtures, but only for repetitive signals. Then there are also air-modulated devices. In these, a compressed air stream is modulated through an electrodynamically actuated valve. In order to ensure good reproduction with a low harmonic distortion factor, the modulation ratio must be kept as small as possible - i.e. the acoustically ineffective constant air flow portion is as high as possible relative to the oscillating component. This worsens the acoustic efficiency in the same proportion. A further loss by a factor of almost 2 results from the fact that the valve modulation not only emits useful sound into the exterior space, but also produces sound output backwards, into the air conduits. In this way, the constancy of the working air pressure is impaired and so the harmonic distortion factor is worsened.

The aim of the invention is to provide a sound generator for the reproduction of sound absorption, speech, music and acoustic signals, which with small structural volumes also has a good distortion-free amplitude response and phase response and a high level of efficiency.

According to the main feature of the invention, the known precision-, micro- and nanomechanical pumps for air, gas or fluids are used for the actuation of a sound generator. Thanks to their small dimensions, these have very short reaction times and are therefore capable of delivering the output flow $q(t)$ necessary for generating a sound signal and the output acceleration $dq/dt = q°(t)$. (q and $q°$ have the dimensions m^3/s and m^3/s^2, t = time). Whereas a conventional loudspeaker functions with large membrane areas and small vibration amplitudes,

with pumps the same output acceleration q°(t) and therefore the same acoustic emissions can be achieved, but with a very much smaller sound radiating opening area. As a result, the dimensions of the sound radiating opening are smaller than the sound wavelengths, so that an acoustic monopole radiator with omnidirectional characteristics - without the troublesome spectral directional characteristics and phase distortion of loudspeakers - can be created. Under free field conditions, the output acceleration q°(t) produces at an immission point at a distance r a sound pressure $p(r, t, -r/c) = \rho q°(t)/4\pi r$. If the sound generator is operated in a one-dimensional channel of cross-sectional area A, the sound pressure is known to be $p(r, t, -r/c) = \rho\ c\ q(t)/A$. For a two-dimensional or generally shaped geometry, comparable conditions apply. (c = velocity of sound, ρ = density in the propagation medium, e.g. air. r/c = sound transit time).

A summarising overview of micro- and nanomechanical pumps is contained, for example, in the book "Grundlagen der Mikrosystemtechnik" [Fundamentals of Microsystems Technology] by G. Gerlach and W. Dötzel, C. Hauser Verlag 1997. The state of development of the other micro- and nanomechanical components is summarised there, especially valves, motors, oscillators, flow, pressure and temperature sensors.

According to a further feature of the invention, pumps with a large output pressure are used to operate sound generators. By connecting several pumps in sequence, the pressure differential can be further increased. The higher the pressure differential, the smaller the buffer volume necessary for operation of the monopole radiator. Compared with the enclosures necessary for membrane loudspeakers, the pressure increase can be used to decrease significantly the operating volume. As a result, buffer volumes and the air conduits are also small compared with the emitted sound wavelength and thus possess only an acoustic reactance, but no resistance, so that no sound output is radiated backwards and so the efficiency and reproduction are not impaired.

According to a further feature of the invention, reversible pumps with compression and suction operation are used. This makes unnecessary the blind airflow necessary with air-modulated devices, and its associated power loss. Furthermore, the reversal helps to recover the positive and negative pressure energy stored in the buffer volume, thus further increasing the efficiency and therefore the operating duration of mobile devices.

According to a further feature of the invention, the sound-generating output flow from the pumps is measured directly using flowmeters or indirectly using pressure and temperature sensors in the buffer volume and readjusted based on a desired value/actual value comparison. The sensors required for this are also known from microsystems technology.

According to a further feature of the invention, pumps and valves oscillating at the same frequency are used, their oscillation frequency being large compared with the useful sound frequency to be radiated. The larger this frequency ratio is, the more exactly the sound signal can be reproduced. Control of the output flow by size and sign is achieved through a phase and/or amplitude adjustment between the pumps and valves. As such, plate springs with piezo actuators or piston pumps driven by phase-adjustable motors and rotary or reciprocating valves can be used.

In order to minimise the periodic intrinsic noise caused by cyclic pump operation directly at the source, double pumps offset by 180° in the clock cycle are used. This allows cancelling-out of the odd-valued noise harmonics. Going beyond this dipole cancelling are two double pumps in a quadrupole arrangement. Even with three individual pumps offset by 120° in the clock cycle, quadrupole cancelling and ideal smoothing of the useful sound-producing air flow are achieved. The periodic intrinsic noise can also be eliminated through sound absorption extinguishing. Further secondary means are absorbing materials, $\lambda/4$ and Helmholtz resonators and acoustic filters and networks that eliminate the high frequency intrinsic noise without impeding the useful sound.

For the middle - and still more for the upper - frequency range, the volume problem becomes lessened. Thanks also to the small volume throughputs, air pumps from the realm of nanotechnology are sufficient. Alternatively, conventional high frequency loudspeakers with frequency dividing networks are possible.

Further features according to the invention concern additional uses. The pumped air stream can, for instance, be employed for cooling electronics and for air filtering and dehumidifying. In many cases, an existing structural volume can be used as a buffer volume. For instance, in a clock with speech reproduction, the display volume between the face and the glass can be used. In other cases it may be the volume - of any shape - above the control electronics.

The subject of the invention will now be illustrated with the aid of several examples. The drawings show the following:

Figs. 1 to 6 Sound generators with buffer volumes and actuated by pumps, whose volume flow can be controlled.

Figs. 7 and 8 Sound generators with buffer volumes and actuated by constantly outputting pumps and control of the volume flow by valves.

Figs. 9 to 12 Sound generators with buffer volumes and oscillating pump output and with oscillating valves.

Fig. 13 Sound generator with storage of kinetic energy in the buffer volume.

Fig. 14 Sound generator in a dipole version (stereo operation).

Figs. 15 to 17 Reduction of the intrinsic noise of the pumps and valves.

Fig. 18 Design of the sound aperture.

In the description, the following designations will be used. (X = number of the Figure) X0 = sound generator; X1 = sound aperture, sound channel; X2, X3, X4 = pump unit, pump actuator, pump components; X5 = buffer volume; X6, X7 = modulation unit, valve, valve components; X8 = sensors for flow, pressure and/or temperature measurement; X9 = acoustic network, protective membranes, other components.

Fig. 1 shows the basic design of a sound generator 10, comprising an air pump 12 and a buffer volume 15. The air throughput - the output acceleration q°(t) - of the air pump 12 is controlled by an integrated pump control 16 according to the sound signal required p (t) and acts on emergence through the sound channel 11 as an acoustic monopole source. This representation applies as long as the radiated sound wavelength is large compared with the diameter of the sound channel 11. With a plurality of such monopole "point" radiators, in known manner, linear, area and volume radiators can be synthesised. Pump systems with sufficiently high working frequencies are known from micro- and nanotechnology, which are also reversible and are suited both to compression and to suction operation. The other pump aperture 11' opens into the buffer volume 15. Acoustically, this has the same function as the enclosure in conventional loudspeakers. In addition, there is a flow sensor 18 in the sound channel 11, via which the output flow or the output acceleration can be determined and adjusted to match a target value. For an indirect flow measurement, pressure sensors positioned in the buffer volume 15 can also be employed. For this

purpose too, microsystems technology has tried and tested measuring systems ready for use. In order to equalise air pressure fluctuations and drift errors of the air pump 12 and the flow sensor 18, there is a bore 19 in the buffer volume 15 with a high flow resistance.

With the sound generator 20 in Fig. 2, the pump 22 with the pump control 26 and the pump medium 24 is sealed off by membranes 21 and 23. The pump medium 24 can be air, a gas or a liquid. In contrast to the open circle as in Fig. 1, this provides a completely hermetic seal, as required, for instance, in a loudspeaker integrated into a clock. The volume displacement of the membrane 21 acts here as a sound emitter and is actuated by the volume-controlled pump 22. A buffer volume 25 serves as equalisation again. This is spherical in shape here, in order to ensure sufficient volume stiffness with a low wall thickness.

Volume control with positive and negative flows - i.e. with compression and suction operation - reduces the number of possible pump systems, so that Fig. 3 describes a sound generator 30 with two identical pumps 32 and 32' which, oriented opposed to each other, have opposite output directions. The (compression) pump 32 feeds air from a buffer volume 35 via the opening 31 to the outside space, and conversely the suction takes place through the opening 31' into the buffer volume 35 via the (suction) pump 32'. The net flow of the openings 31 and 31' decisive for the sound radiation can be regulated indirectly via a pressure sensor 38, which measures the pressure in the buffer volume 35. In order to increase the pressure differential, two - or more - (compression) pumps 32 and (suction) pumps 32' are connected one after the other. A doubling of the pressure halves the buffer volume. The sound generator 40 according to Fig. 4 consists of a large number of compression pumps 42 and a similar number of suction pumps 42'. These are connected between the sound apertures 41 allocated to them and a buffer volume 45. The compression and suction pumps 42 and 42' are set to continuous operation conditions. The sound-generating, resultant output flow is controlled here only through the number of compression and suction pumps 42 and 42' that are switched on or off. Since the time and manufacturing cost for micro- and nanomechanical components is practically independent of their number, it may be advantageous, instead of just one pump, to use a plurality of smaller pumps. With decreasing size, the reaction and run-up times of suction and compression pumps 42, 42' falls. In order to cover a larger dynamic range, it is advantageous to employ two or more pump sizes. A graduation of this type is also better suited to the different output flows for low and high frequency sound radiation.

The sound generator 50 according to Fig. 5 with a buffer volume 55 and pressure sensor 58 is actuated using a flagella pump principle. This principle is used in nature for propulsion by the Mastigophora, or flagellates. For this purpose, several waveguides 52 for mechanical transverse waves are installed in the channel of the sound aperture 51. At the ends of the waveguides 52, there are vibration exciters 54 and 54'. The vibration exciter 54 produces a bending or vibrating-string wave in the waveguide 52 with a frequency very much higher than the sound frequency to be radiated, and which propagates towards the sound aperture 51. The interaction of the wave with the surrounding medium - e.g. air or liquid - exerts a force on this and thus a flow towards the sound aperture 51. Through the output of the vibration exciter, the sound-creating output flow can be controlled. In the same way, the output flow directed in the opposite direction is controlled by the vibration exciter 54'. It is known from the theory of flagellar propulsion that the interaction force achievable and thus also the output air or liquid quantity of interest here is larger the smaller the speed of the bending wave and the smaller the intrinsic losses of the waveguide 52. Thin walled strips and wires made of metal and fibre-reinforced plastics fulfil these requirements. In general, the wave has not yet fully decayed when running through the waveguide 52. As known from anti-vibration technology (AVC = active vibration control), the vibration exciters 54 and 54' can serve as mutually active vibration absorbers.

In Fig. 6, the sound generator 60 consists of a buffer volume 65, a compression pump 62 with the output opening 61, and a suction pump 62' with the intake opening 61'. Both pumps 62 and 62' - e.g. of the Roots blower type - are actuated by one motor 63 via a differential gear 64. Also on the pump shaft are sited the control (braking) motors 66 and 66'. If different turning moments are produced by these then - as is known from a motor car differential - the rotary speed of the pumps 62 and 62' and thus the output volumes can be specifically adjusted.

The examples according to Figs. 7 and 8 show sound generators 70 and 80 actuated by constant output pumps and in which control of the sound-generating air flow is achieved with valves. In Fig. 7, a pump 72 draws air out of a negative pressure volume 75' into a positive pressure volume 75. The control valve 76 releases air via an opening 71 to the outside space to be irradiated. In a similar manner, air is drawn via the valve 76' through the opening 71'. The output quantity of the pump 72 depends on the sound output to be radiated and is adjusted to this. In order to have a reserve for sudden volume increases, a certain degree of storage is suitable - in Fig. 8, however, there is only one buffer volume 85 with a constantly outputting pump 82 and the rotary valves 86 and 86'. Through the setting angle of the valve 86, the ratio between the air flow to the outside

and that into the buffer volume 85 can be adjusted, similarly to that of the suction flow via the rotary valve 86'. The net air flow to the outside gives the sound signature. In order to make a much more effective acoustic monopole radiator out of the primary dipole radiator, the change of air flows is again balanced through the buffer volume 85. The sound apertures 81 and 81' are preceded by a chamber volume 89, which with the sound aperture 81" comprises a low pass filter and suppresses the high frequency intrinsic sounds of the sound generator 80.

The examples in Figs. 9 to 12 have clocked pumps and valves with a clock frequency that is higher than the sound frequency to be radiated. In Fig. 9, the pump piston 92 and the oscillating valves 96 and 97 vibrate with the same frequency. The positions shown with dotted lines represent the pump piston 92 and the oscillating valves 96 and 97 in the opposing amplitude position. In order to avoid the reactive operating forces - the unwanted blind forces - all three elements 92, 96 and 97 are adjusted to the same resonant frequency, although they can be adjusted relative to each other with respect to their phase and amplitude. An adjustment of this type is made for instance with the actuator. With the flat design of the elements 92, 96 and 97 in Fig. 9, piezoelectric activators are suitable. Due to the mutual phase position, the acoustically effective output flow at the opening 91 can be adjusted for direction and size. The output flow dependent on the sound output to be radiated is adjusted by means of the vibration amplitudes of the pump piston 92. In the event of large dynamic variations, a certain output excess is suitable. Instead of the vibration actuation with piezoelectric actuators, pump pistons 92 and the valves 96, 97 can be designed in a rotary version (see Fig. 11) and actuated with phase-controllable motors. In order to achieve monopole radiation again, a buffer volume 95 is provided. This can be dispensed with if the sound apertures 91 and 91' operate on two acoustically separate spaces. This occurs, for instance, if the sound generator 90 is built into a channel wall and one of the sound apertures 91 and 91' opens into the channel space and one into the outside space.

In Fig. 10, the buffer volume 105 of a sound generator 100 is designed as a $\lambda/2$ resonator. By means of the oscillating piston 102, a standing wave is created. The intrinsic resonance of the oscillating valve 106 is tuned to the $\lambda/2$ resonance. Using the phase length and the amplitudes of the vibrating piston 102 and the oscillating valve 106, the volume flow can be controlled again at the aperture 101, with respect to direction and amount.

In Fig. 11, two standing λ/2 waves arise in the volumes 115 and 115', actuated by the oscillating piston 112, which in their phases are displaced by 180°. Therefore at the apertures 111 and 111', the opposite sound pressure always exists. A valve disk 116 actuated by the motor 117 at a rotary frequency equal to the frequency of the λ/2 oscillation has openings and is closed at the side radially opposite them. At a phase position in which under positive pressure, access to the sound aperture 111 is given, air is output to the outside; in a phase position with negative pressure, suction occurs. In the middle position, however, no resultant air flow occurs at the openings 111 and 111'. Here, too, the phase position and amplitude of the useful sound-producing air flow can be controlled as regards direction and amount.

The example according to Fig. 12 is the two-dimensional analogue of the one-dimensional embodiment according to Fig. 10. Two orthogonal oscillating pistons 122 and 122' impinge upon the two-dimensional buffer volume 125 and excite λ/2 oscillations in the horizontal and vertical directions. Two oscillating valves 126 and 126' are attuned to the frequencies of the oscillating pistons 122 and 122'. By means of their phase position, as in the one-dimensional case, the sound-generating air flow from the openings 121 and 121' can be controlled.

The buffer volume 135 in Fig. 13 stores not only pressure energy, but also kinetic energy. To this end, the air in the buffer volume 135 is made to rotate by a substantially constantly rotating rotor 132. On the periphery of the buffer volume, a valve flap 136 is arranged. In the position 136', the air is output to the outside, while in the opposite position 136", the rotation motion draws air in from outside according to the principle of the gas jet pump. This principle can be extended in that a second buffer volume in a state of rest is also attached.

Fig. 14 shows a sound generator 140 in a two-pole version, as suited, for example, to stereo reproduction or in the realisation of an acoustic dipole. To that end two independent pump actuators 142 and 142' are provided with the associated loudspeaker apertures 141 and 141'. Each unit can be designed according to one of the examples in Figs. 1 to 12. In place of individual buffers, only one common buffer volume 145 is provided here. In an extreme case, this may degenerate into a connecting pipe. In multipole loudspeaker systems, a common buffer volume may also be advantageous for all the individual poles. The same applies for an array arrangement for directional sound radiation. Standing waves in the buffer volume 145 are damped with sound absorbers 149.

The embodiments according to Figs. 15 to 17 concern means to eliminate the cyclic and other intrinsic sounds of the pumps and valves. In Fig. 15, cancellation by destructive interference takes place in that two openings 151 and 151' are brought together by pumps and valves displaced in the clock cycle by 180°. Such an arrangement converts a monopole radiator into a less effective dipole. A four-unit arrangement with a quadrupole character provides a further reduction of the cyclic noises. The useful sound is not thereby affected. In Fig. 16, the aperture channel 161 is filled with sound absorbent fibrous materials 169. The unwanted sound from the high frequency operating pumps and valves is very much more strongly damped than the lower frequency useful sound. At the same time, dust filtering can be effected with the fibrous materials 169. Finally, in Fig. 17, the loudspeaker channel 171 is provided - here - with Helmholtz resonators 179. In this way, without affecting the useful sound, the cycle frequency and its harmonics can be absorbed or damped. Thus, the acoustically useful volume flow of the loudspeaker channel 171 is also smoothed.

In Fig. 18, the sound channel 181 has a cross-sectional extension. This extension is designed as an aerodynamic diffuser and is used for large output flows - i.e. with large flow speeds - to ensure a reversible pressure equalisation without loss-producing extensions. With channel subdivisions - not shown here - even with short channel lengths, an adjacent, eddy-free flow can be sustained. In a general case, the design of the sound channel 181 as a diffuser does not fulfil the requirements of an acoustic horn. Naturally, however, a horn can also be added on. Finally, the sound channel 181 is provided with a protective grid 189 against dirt and unwanted contact.

Claims

1. Sound generator for sound absorption and for signal, speech and music reproduction from the infrasound to the ultrasound range, characterised by one or more of the following features:

a) The sound generator possesses a pump system, comprising a pump and modulation device, a buffer volume and a sound aperture

b) The pump system is arranged between the buffer volume and the sound aperture and outputs a modulated fluid volume flow through the sound aperture

c) The uniflow current component of the fluid volume flow is zero

d) A sensor records the physical data of the pump system, the fluid in the buffer volume, the fluid volume flow, or the emitted sound pressure, in high temporal resolution and passes the data to a control unit, which controls or regulates the pump system

e) The pump frequency of the pump system is larger than or the same as the modulation frequency of the useful sound

f) The modulated fluid volume flow produces pressure changes in the buffer volume and acoustic monopole radiation at the sound aperture

i) The modulated fluid volume flow produces, through impulse transfer to the surroundings, as well as monopole radiation, also dipole radiation, and directional sound radiation results.

2. Sound generator according to Claim 1, characterised by one or more of the following features:

a) As pump, one of the pumps known from precision-, micro- or nano-technology, or one of the pumps described in the figures is used

b) The pump belongs to the types piston, membrane, rotary pump or another of the known pump types or is a ventilator, compressor, blower, turbine or flagella pump

c) The pump comprises a flexible, actively steerable wall in the buffer volume

d) The pump produces volume displacement and/or pressure build-up through turning, oscillating or rotating parts and/or through known mechanical waveguides

e) The pump has a fixed supply direction or the pump can be reversed and has suction and compression operation

f) The pump supplies an analogue or digital fluid volume flow

g) The actuation of the pump and/or the modulation device takes place with electric motors, piezoelectric elements, mechanical, hydraulic or pneumatic actuators or other known actuators

h) The pump system or the actuator of the same is cooled by the fluid itself or by thermal radiation.

3. Sound generator according to at least one of the Claims 1 and 2, characterised by one or more of the following features:

a) The buffer volume possesses a pressure-resistant housing with at least one opening, in which the pump system or parts thereof are mounted

b) As the buffer volume, a channel, ring channel or a spiral, disc, box or spherical shaped hollow space or an already existing hollow space can be used

c) A plurality of buffer volumes are connected and/or coupled acoustically or with regard to vibrations via movable separating walls or vibrating components

d) Standing waves in the buffer volume are damped by known passive absorbers and/or active sound damping measures

e) The pump systems, instead of being built onto a buffer volume, are built into a wall or attached to a large fluid volume

f) In the buffer volume, as well as through the pressure of the fluid, energy is temporarily stored through a fluid flow or through reactive deflection of components.

4. Sound generator according to at least one of the Claims 1 to 3, characterised by one or more of the following features:

a) It possesses at least one sound aperture

b) The sound aperture and/or other apertures of the sound generator are sealed with membranes

c) At the sound aperture, an aerodynamic diffuser is mounted

d) In order to damp the cyclic or other intrinsic sounds of the pump system, active or passive sound dampers or resonators are used

e) In front of and behind the sound aperture are situated reactive elements (Helmholtz or $\lambda/4$ resonators) or an acoustic network for sound amplification or filtering

f) An acoustic horn is mounted at the sound aperture

g) The sound aperture possesses a grid or fabric as dust and contact protection.

5. Sound generator according to at least one of the Claims 1 to 4, characterised by one or more of the following features:

a) The modulation device consists at least of valves or another known device for fluid modulation that is integrated into the pump or is separate

b) The pump itself or the modulation device modulates the fluid volume flow through variation of the pump frequency, a variable pump stroke, through the switching on and off of individual pumps or channels, the cyclic, amplitude or phase relationship between the modulation device and the pump or a plurality of pumps, via standing waves in the buffer volume or via a siren mechanism or combinations of these

c) The valves modulate the fluid volume flow through amplitude, frequency or phase control or a plurality of valves modulate the fluid volume flow through the closing and opening of individual valves

d) In a pump with one supply direction, the fluid volume flow is guided by two valves in front of and behind the pump, according to the fluid volume flow modulation to be achieved, or through flow deflection outwards or into the buffer volume, respectively

f) Passive modulation takes place in that the entire pump system or parts thereof or the fluid in the buffer volume or in the sound aperture undergo natural oscillation

g) The frequency-dependent functioning of the pump system and/or losses or non-linearities in the compression by the pump system are taken into account with a suitable treatment of the control signal

h) Two pumps operate at high frequency with almost the same frequency and generate low-frequency useful sound radiation, according to the Tartini effect

i) Two or more pump systems or parts thereof with the same or opposing output directions are linked electrically or mechanically, in order, by influencing the coupling, to achieve a modulation as illustrated by way of example in Fig. 6.

6. Sound generator according to at least one of the Claims 1 to 5, characterised by one or more of the following features:

a) The sensor is situated on or within the sound aperture, in the pump system or in the buffer volume and records the pressure, temperature, fluid volume flow, the speed of the fluid volume flow, and/or the sound pressure outside the pump or another variable characterising the fluid volume flow or movements of the pump system

b) The system needs no sensor if the behaviour of the pump is known and/or no great demands are placed on the sound fidelity of the sound generator.

7. Sound generator according to at least one of the Claims 1 to 6, characterised by one or more of the following features:

a) The pump system possesses one or a plurality of pumps of the same or graduated size, type, pump frequency and stroke

b) A plurality of apertures or a plurality of sound generators form one-, two-, three-dimensional acoustic arrays or an end-fired line or a two-pole arrangement, whereby in a manner known in itself, through amplitude, frequency and/or phase adjustment, any desired directional characteristic can be realised

c) The pump systems, the pumps or parts thereof are connected in series or parallel

d) The sound generator is positioned within a pipe, around a pipe or on a pipe, whereby the sound radiation takes place through the sound aperture in the pipe.

8. Sound generator according to at least one of the Claims 1 to 7, characterised by one or more of the following features:

a) The pump system functions self-sufficiently without control, possesses only one energy supply and modulates through natural oscillation or another automatic system

b) The pump system possesses a control system or regulator, whereby this takes account of the acoustic radiation or another physical variable of the pump system, the fluid flow or the buffer volume via a sensor signal, as a control or regulating variable

c) In order to equalise air pressure variations and drift errors, the buffer volume has an additional opening with a large flow resistance.

9. Sound generator according to at least one of the Claims 1 to 8, characterised by one or more of the following features:

a) The sound generator is integrated into small articles such as watches, mobile telephones, remote control units, pens, spectacles, jewellery, bank cards, keyboards, screens, key rings, toys, household items, hearing aids and other components, whereby not used or specially designed dead volumes are used as buffer volumes

b) The sound generator is integrated into existing loudspeaker systems or enhances them

c) The sound generator is attached to mobile or rotating components

d) The sound generator is employed for cancellation by destructive interference according to the rules of sound absorption technology

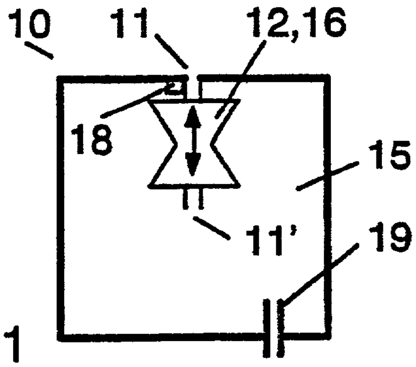

Fig. 1

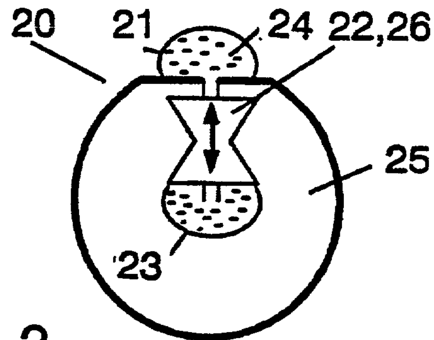

Fig. 2

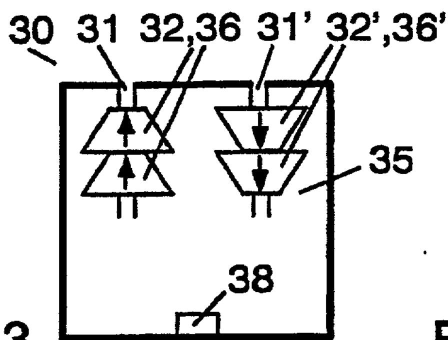

Fig. 3

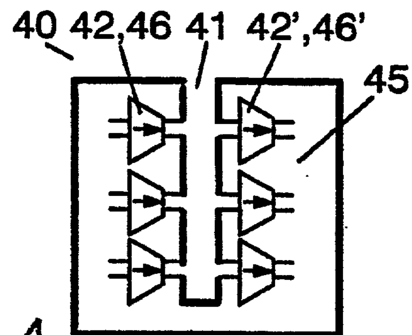

Fig. 4

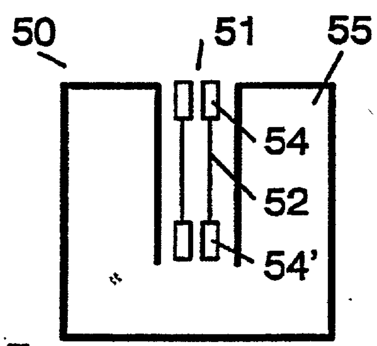

Fig. 5

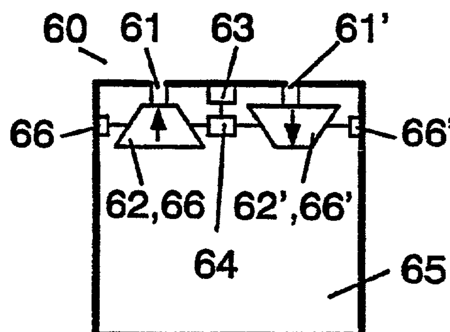

Fig. 6

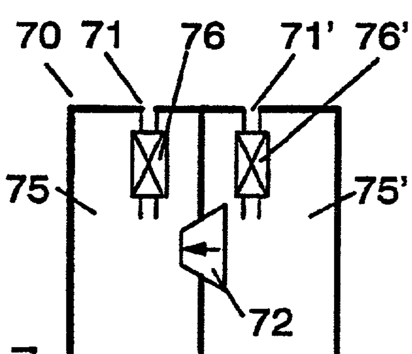

Fig. 7

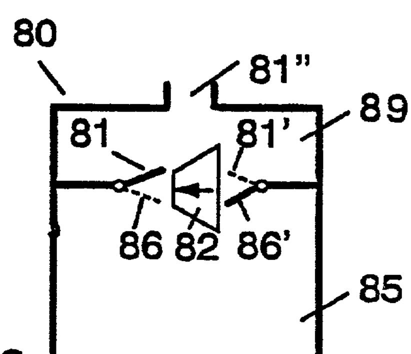

Fig. 8

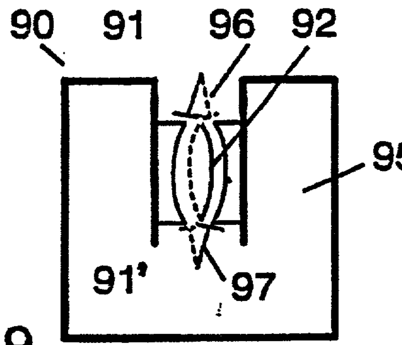

Fig. 9

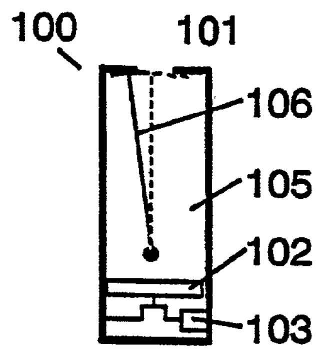

Fig. 10

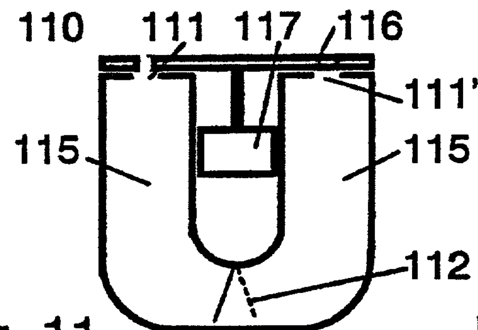

Fig. 11

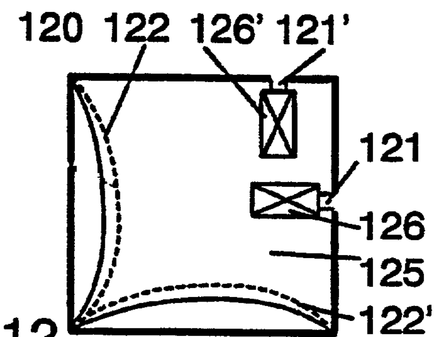

Fig. 12

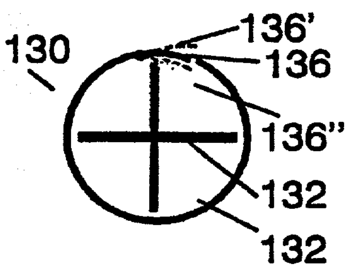

Fig. 13

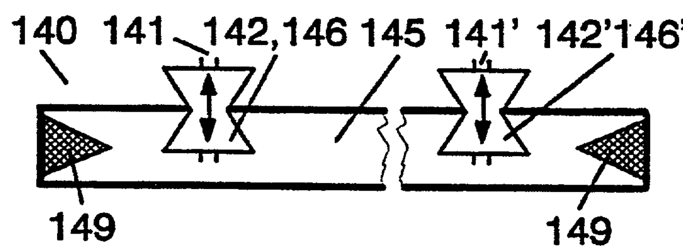

Fig. 14

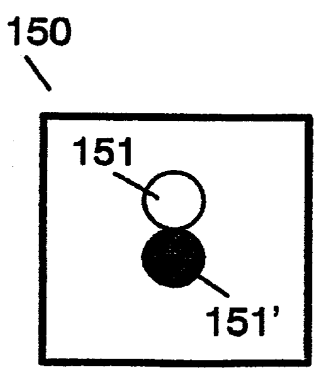

Fig. 15

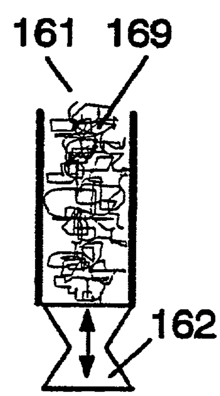

Fig. 16

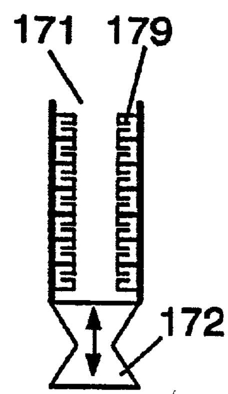

Fig. 17

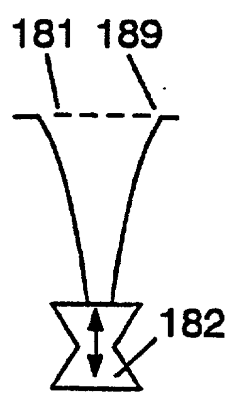

Fig. 18

#3

Atty. Dkt. No. 085874-0353

DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I HEREBY DECLARE:

THAT my residence, post office address, and citizenship are as stated below next to my name;

THAT I believe I am the original, first, and sole inventor (if only one inventor is named below) or an original, first, and joint inventor (if plural inventors are named below or in an attached Declaration) of the subject matter which is claimed and for which a patent is sought on the invention entitled

SOUND GENERATOR WITH A PUMP ACTUATOR

(Attorney Docket No. 085874-0353)

the specification of which (check one)

__ is attached hereto.

X was filed on January 28, 2000 as United States Application Number or PCT International Application Number PCT/DE00/00252 and was amended on August 1, 2001 (if applicable).

THAT I do not know and do not believe that the same invention was ever known or used by others in the United States of America, or was patented or described in any printed publication in any country, before I (we) invented it;

THAT I do not know and do not believe that the same invention was patented or described in any printed publication in any country, or in public use or on sale in the United States of America, for more than one year prior to the filing date of this United States application;

THAT I do not know and do not believe that the same invention was first patented or made the subject of an inventor's certificate that issued in any country foreign to the United States of America before the filing date of this United States application if the foreign application was filed by me (us), or by my (our) legal representatives or assigns, more than twelve months (six months for design patents) prior to the filing date of this United States application;

THAT I have reviewed and understand the contents of the above-identified specification, including the claim(s), as amended by any amendment specifically referred to above;

THAT I believe that the above-identified specification contains a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the invention, and sets forth the best mode contemplated by me of carrying out the invention; and

THAT I acknowledge the duty to disclose to the U.S. Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

002.617254.1

I HEREBY CLAIM foreign priority benefits under Title 35, United States Code §119(a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate, or §365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below any foreign application for patent or inventor's certificate or of any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number	Country	Foreign Filing Date	Priority Claimed?	Certified Copy Attached?
199 04 106.7	Germany	February 2, 1999	YES	

I HEREBY CLAIM the benefit under Title 35, United States Code § 119(e) of any United States provisional application(s) listed below.

U.S. Provisional Application Number	Filing Date

I HEREBY CLAIM the benefit under Title 35, United States Code, §120 of any United States application(s), or § 365(c) of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. Parent Application Number	PCT Parent Application Number	Parent Filing Date	Parent Patent Number

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to have full power to prosecute this application and any continuations, divisions, reissues, and reexaminations thereof, to receive the patent, and to transact all business in the United States Patent and Trademark Office connected therewith.

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I UNDERSTAND AND AGREE THAT the foregoing attorneys and agents appointed by me to prosecute this application do not personally represent me or my legal interests, but instead represent the interests of the legal owner(s) of the invention described in this application.

I FURTHER DECLARE THAT all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

1-00

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2-CO

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Date	9. September 2001

002.617254.1

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